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I, KIM MARSHALL, MANAGER EXAMINATION SUPPORT AND SALES, hereby certify that the annexed is a true copy of the Provisional specification in connection with Application No. PP 1545 for a patent by PARAKAN PTY LTD filed on 29 January 1998.

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KIM MARSHALL
<u>MANAGER EXAMINATION SUPPORT AND SALES</u>

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:-

"A TRANSCEIVER"

The invention is described in the following statement:-

Field of Invention

The invention relates to a transceiver and a method for transmitting data.

The invention has been developed primarily for the field of Radio Frequency Identification (RFID) and will be described hereinafter with reference to that application. However, it will be appreciated that it is not limited to that particular field of use.

Background of the Invention

In prior art systems passive RFID transponders have included a receiving antenna and a transmitting antenna. The need for separate antennae adds to the cost and complexity of the transponder. To address this limitation a number of single antenna transponders have been developed. That is, the transponder's antenna is used to both receive signals and transmit signals. Generally, these antennae are tuned to the received or interrogating frequency and, as such, the transmitted frequency can not differ greatly from the received frequency otherwise the antennae will not broadcast the transmitted signal efficiently. Examples of such known systems are disclosed in AU 55902/86, US 4,546,241, US 4,517,563, US 4,075,632, US 4,038,653, US 3,832,530 and US 3,299,424. The transmission efficiency of all these systems is degraded by this tuning arrangement and otherwise compromised by the stray capacitance of the antenna coil.

Object of the Invention

It is an object of the present invention, at least in the preferred embodiments, to overcome or substantially ameliorate one or more of the deficiencies of the prior art.

Summary of the Invention

According to a first aspect of the invention there is provided a transceiver including:

an antenna for receiving a first signal and, in response thereto, generating a second signal, the first signal having a first predetermined frequency;

receiving circuitry being responsive to the second signal;

tuning circuitry for providing the antenna with a resonant frequency at or about the first predetermined frequency; and

a modulator disposed between the antenna and the tuning circuitry for varying the impedance therebetween such that the second signal generates a third signal in the

antenna at a second predetermined frequency whereby the antenna transmits a fourth signal derived from the third signal.

Preferably, the first and second predetermined frequencies are substantially different.

Preferably also, the antenna includes a coil and the tuning circuit includes a capacitor connected in parallel with the coil. More preferably, the antenna consists of a coil and the tuning circuit consists of a capacitor. Even more preferably, the modulator is connected in series with the capacitor.

In a preferred form, the receiving circuitry, in response to the second signal, actuates the modulator to provide the third signal. More preferably, the third signal is modulated in accordance with a data signal specific to that transceiver. Even more preferably, the data signal is stored in the receiving circuitry and selectively provided to the modulator.

Preferably, the second signal is the current generated in the antenna by the first signal. In other embodiments, however, the second signal is the voltage induced across the tuning circuitry by the first signal.

According to a second aspect of the invention there is provided a tuned antenna including:

a coil for receiving a first signal having a first predetermined frequency;

a capacitor connected in parallel with the coil for providing the antenna with a resonant frequency at or about the first predetermined frequency; and

a modulator disposed in series with the capacitor for providing a varying impedance such that the second signal generates a third signal in the coil at a second predetermined frequency whereby the coil transmits a fourth signal derived from the third signal.

According to a third aspect of the invention there is provided a method for receiving and transmitting a first signal and a fourth signal respectively to and from a transceiver, the method including the steps of:

receiving the first signal with an antenna and, in response thereto, generating a second signal, the first signal having a first predetermined frequency;

providing the second signal to receiving circuitry;

tuning the antenna with tuning circuitry to have a resonant frequency at or about the first predetermined frequency; and

varying the impedance between the antenna and the tuning circuitry such that the second signal generates a third signal in the antenna at a second predetermined frequency whereby the antenna transmits a fourth signal derived from the third signal.

According to another aspect of the invention there is provided a method for receiving and transmitting a first signal and a fourth signal respectively, the method including the steps of:

receiving with a coil a first signal having a first predetermined frequency;

connecting a capacitor in parallel with the coil for providing the antenna with a resonant frequency at or about the first predetermined frequency;

generating a second signal from the first signal; and

disposing a modulator in series with the capacitor for both providing a varying impedance such that the second signal generates a third signal in the coil at a second predetermined frequency whereby the coil transmits the fourth signal which is derived from the third signal.

In the preferred embodiments the antenna is a coil tuned by a capacitor. To transmit a signal from this type of single antenna transceiver (also known as a transponder) the current flowing in the coil is modulated or varied in some predetermined manner. Most preferably, this is achieved by the use of a small variable resistance in series between the antenna and the tuning capacitor to cause a variation in the current generated by the coil. In the preferred embodiment the small series resistance is modulated with an RF carrier and data is modulated onto the carrier for transmission by the antenna. Varying or modulating the value of this small resistance causes rapid changes in the current flowing in the coil that are not limited by the antenna tuning. Accordingly, the preferred embodiments allow simultaneous reception at the first predetermined frequency and transmission at a second predetermined frequency different from the first.

Some embodiments of the invention allow transmission of data from the transceiver or transponder at more than two distinct frequencies using a single tuned antenna. This invention, therefore, has particular merit when applied to passive RFID

transponders such as those used in a baggage handling system at airports, bus terminals, train stations and the like, and for parcel handling and courier applications.

The preferred embodiments overcome the prior art limitation on the transmission frequency having to be similar to the receive frequency, as they allow the transmission frequency to be completely decoupled from the tuned receiving frequency of the antenna. This, in turn, enables the transmission of higher or lower frequency signals from transponders with antennas tuned either lower or higher respectively than the transmission frequency.

Drawings

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic circuit diagram of a prior art transceiver or transponder circuit;

Figure 2 is an AC electrical model for the circuit of Figure 1;

Figure 3 is a schematic circuit diagram of a tuned antenna according to the invention;

Figures 4(a) and 4(b) are electrical models of the antenna of Figure 3 at the tuned frequency and at a higher radio frequency respectively;

Figures 5(a), 5(b), 5(c) and 5(d) illustrate various exemplary waveforms for the circuit of Figure 3;

Figures 6(a), 6(b), 6(c), and 6(d) illustrate frequency spectra associated with the waveforms of Figures 5(a) to 5(d);

Figures 7(a), 7(b), 7(c) and 7(d) illustrate various alternative impedance modulating arrangements;

Figures 8(a) and 8(b) respectively illustrate schematically two alternative embodiments of a transceiver according to the invention;

Figure 9 is a schematic circuit diagram of another preferred embodiment of a transceiver according to the invention;

Figure 10 is a schematic representation of a baggage item with a RFID transponder label embodying the invention;

Figure 11 is an enlarged schematic representation of the label shown in Figure

10, in the unfolded configuration;

Figure 12 is a further enlarged schematic representation of the coil, tuning capacitor and receiving circuitry of the label of Figure 11; and

Figure 13 is a still further enlarged schematic representation of the receiving circuitry and the tuning capacitor.

Description of Selected Preferred Embodiments of the Invention

In the following explanation of the invention there is description using both the time and frequency domain methods. It will be appreciated by those skilled in the art that the time domain methods provide information on the transient behaviour of the invention while the frequency domain methods are used to interpret the AC electrical behaviour. It will also be appreciated that the terms “transponder” and “transceiver” are used interchangeably.

RFID transponders that incorporate a single antenna may be interrogated with an interrogating or exciting field. This field is received by the transponder’s antenna and the voltage induced on the antenna may be rectified and used to power the transponder. It is necessary that the transponder be able to transmit messages back to its interrogator. For single antenna transponders the transmitted signal must be radiated off the same antenna that is used to receive the interrogating signal.

In prior art systems a resistance is provided in parallel with the antenna and is modulated to change the current produced by the antenna. By way of example, Figure 1 illustrates a prior art system where the antenna coil L is tuned by capacitor C and a resistance $R_{(modulator)}$ is switched in parallel with the coil. A rectifier (half or full wave) converts the AC voltage to a DC voltage which is stored on a DC storage capacitor C_{dc}. The transponder circuit load is represented by the load resistor $R_{(chip)}$.

Figure 2 shows an AC electrical model for the prior art tuned coil. The transient response of the coil is determined by the total Q factor Q_t and:

$$1/Q_t = 1/Q_c + 1/Q_i \qquad (1)$$

where Q_c is the tuning capacitor Q factor $Q_c = wRC$ and Q_i is the coil Q factor given by wL/r_{ac}. The resistance R is the equivalent parallel AC resistance of $R_{(modulator)}$ and $R_{(chip)}$, r_{ac} is the series AC resistance of the coil and w is the angular frequency in radians. The

time constant T_s for the sinusoidal transient response of this circuit to either sinusoidal excitation or a component parametric change is given by:

$$T_s = 2Q_t/w. \quad (2)$$

The bandwidth (BW) of the tuned circuit is:

$$BW = 1/T_s.PI = w/Q_t.2.PI. \quad (3)$$

Such a tuned circuit is only able to pass signals within its bandwidth. Furthermore, the voltage of inertia of the DC storage capacitor C_{dc} clamps the antenna voltage through the rectifiers and prevents high speed modulation of the voltage across the antenna. These fundamental limitations of the prior art do not occur in the following preferred embodiments of the invention which are described below.

More particularly, Figure 3 illustrates schematically a preferred embodiment of a tuned antenna according to the invention. A coil L is tuned with a capacitor C. A modulated series resistance $R_{(modulator)}$ is placed between the coil and the tuning capacitor. The coil is excited by the interrogator signal having an AC voltage V_{ac} as its resonant frequency. This causes a resonant current I_{ac} to flow between the coil and the tuning capacitor through $R_{(modulator)}$. A voltage $V_{(modulator)}$ appears across $R_{(modulator)}$, where:

$$V_{(modulator)} = Iac.\ R_{(modulator)} \quad (4)$$

If $R_{(modulator)}$ is modulated to a depth of $\Delta R_{(modulator)}$ then the change in magnitude of $V_{(modulator)}$ is $\Delta V_{(modulator)}$ where:

$$\Delta V_{(modulator)} = I_{ac}.\Delta R_{(modulator)} \quad (5)$$

Switch SW1 in Figure 3 represents a modulator that varies the impedance of series resistor $R_{(modulator)}$. For simplicity a switch is illustrated, however, and as would be appreciated by those skilled in the art, any means of achieving a controlled variable impedance can be substituted. In this embodiment the switch is modulated with a signal that is either a baseband signal or a carrier frequency with data modulated on to the carrier for transmission. Typically the carrier frequency is chosen in the range from a few hertz to thousands of times the excitation frequency. The preferred method of data modulation onto the carrier is Phase Reverse Keying PRK. The modulator SW1 is switched so that it spends a fraction of its time (typically 50%) open and the balance closed. Consequently, the modulator presents an average resistance (typically 50%) of

its value to the circuit at the resonant frequency.

The envelope of the voltage across the antenna follows the openings and closures of the switch. When the switch is closed the antenna voltage is equal to the tuning capacitors instantaneous voltage and when the switch is open the antenna voltage is equal to the tuning capacitors instantaneous voltage plus $V_{(modulator)}$.

Figures 4(a) and 4(b) illustrate the electrical model of the invention at the tuned frequency and at a higher radio frequency respectively.

The invention can be described in general terms using the "Compensation Theorem". The Compensation Theorem is as follows:

> If the impedance of a branch carrying a current I is increased by ΔZ then the increment in current and voltage in each branch of the network is the same as would be produced by an opposing voltage $\Delta V = I\Delta Z$ introduced in series with ΔZ in the same branch.

This theorem is expanded upon in "Electrical Engineering Circuits" 2nd edition H.H Skilling page 373, the contents of which are incorporated herein by way of cross reference.

Using the Compensation Theorem it becomes evident that the modulator resistor can be replaced by an equivalent series voltage source $\Delta V_{(modulator)}$ and $R_{(modulator)}$. Under superposition the voltage source $\Delta V_{(modulator)}$ will cause a current I_{mod} to flow in the tuned circuit. The magnitude of I_{mod} is limited by the series impedance of the coil and capacitor combination and $R_{(modulator)}$. The modulation current I_{mod} in the coil will transmit the modulation as a magnetic field. The strength of the transmitted signal is proportional to the magnetic moment which is given by the product of the coil current I_{mod}, the coil area and the number of turns.

The tuned model of figure 4(a) shows the coil L, the coil's AC resistance r_{ac} and the tuning capacitor C. The modulation resistance has been replaced by the Compensation Theorem equivalent series combination of $\Delta V_{(modulator)}$ and $R_{(modulator)}$. The magnitude of current I_{mod} flowing in the coil is limited by the series impedance of the coil and capacitor combination, r_{ac} and $R_{(modulator)}$.

In this embodiment $R_{(modulator)}$ is modulated at radio frequencies (RF) and, as such, an RF model of the invention, as shown in figure 4(b), is used to analyse the circuit. At

radio frequencies the tuning capacitor C is replaced with an RF short circuit and the coil's parallel stray capacitance C_s is added. Unlike the prior art circuits the tuning capacitor now has no effect upon circuit operation. Furthermore, for typical values of C_s the series impedance of C_s is much higher than $R_{(modulator)}$ and, consequently, this has little or no effect upon the magnitude of the current I_{mod} in the coil. I_{mod} is now only limited by the coil impedance, r_{ac} and $R_{(modulator)}$.

For an RF frequency of around 3MHz some typical circuit values are as follows: $R_{(modulator)} = 10\Omega$; $\Delta R_{(modulator)} = 5\Omega$; $I_{ac} = 25mA$; $L = 250uH$; $r_{ac} = 25\Omega$; $C_s = 100pF$; and $C = 5.6nF$. Hence $V_{(modulator)} = 125mV$ and $I_{mod} = 26.5uA$. For a coil with 50 turns and an area of 80mm by 50mm the magnetic moment will be 5.3uA.turns.m^2.

Where a carrier frequency lower than the resonant frequency is used the compensation theorem still holds and the envelope of the coil voltage follows the tuning capacitor voltage plus $V_{(modulator)}$. Consequently, the current through the coil is modulated by $R_{(modulator)}$ regardless of the carrier frequency.

Figures 5(a), 5(b), 5(c) and 5(d) show various exemplary waveforms of the invention. Figure 5(a) shows the coil resonant current I_{ac}. Figure 5(b) shows the magnitude of $R_{(modulator)}$ when modulated with a carrier frequency higher than the resonant frequency. The nominal change in $R_{(modulator)}$ is between 0 and $R_{(modulator)}$. Figure 5(c) shows the magnitude of the voltage across the modulation resistance. The phase of the carrier frequency is varied 180 degrees at the zero crossing of I_{ac} to compensate for the sign change in I_{ac} and, consequently, there is no phase change in the current I_{mod}. The envelope of I_{mod} is modulated by I_{ac} and resembles a full wave rectified sine wave. Figure 5(d) shows the magnitude of the voltage across the modulation resistance where the resistance has been scaled to compensate for the variation in the magnitude of I_{ac}. The magnitude of $R_{(modulator)}$ may be varied in discrete steps or continuously over each half cycle of I_{ac} to effectively waveshape I_{mod}. If the carrier frequency is lower than the resonant frequency then waveshaping to compensate for the envelope of I_{ac} is not necessary.

Figures 6(a), 6(b), 6(c), and 6(d) show typical frequency spectra associated with Figures 5(a) to 5(d). More particularly, Figure 6(a) illustrates the spectrum of a full wave rectified version of the sine wave current I_{ac}. The full wave rectified signal has a

DC component and substantial even harmonics in its spectrum. Figure 6(b) illustrates the spectrum of the higher frequency carrier that has already been modulated with data. Figure 6(c) illustrates the spectrum of the resulting voltage across $R_{(modulator)}$. The data spectrum has been modulated on to the spectral lines of the full wave rectified spectrum of I_{ac} and translated in frequency up to the carrier frequency. When waveshaped, the extra harmonic sidebands are suppressed as shown in Figure 6(d). Simple four step shaping of $R_{(modulator)}$ will suppress all the sidebands to less than -20dBc.

Figures 7(a) to 7(d) show various modulators for varying the impedance $R_{(modulator)}$. The switch shown in Figure 7(a), in other embodiments, includes a FET or BJT switch as schematically illustrated in Figure 7(b). Alternatively, Figure 7(c) illustrates solution how the channel resistance of a FET is used to create a specific switchable series resistance. Figure 7(d) shows an arrangement where the value of the series resistance is varied between several values to allow waveshaping of the amplitude of $V_{(modulator)}$.

Figures 8(a) and 8(b) show two alternate embodiments of a transceiver according to the invention. In Figure 8(a) the transceiver includes transponder circuitry which is connected across the antenna coil. In Figure 8(b) the transponder circuitry is connected across the tuning capacitor. In this manner only the resonant current I_{ac} passes through the modulator. The current for the transponder's rectifier circuit I_{rect} does not pass through the modulator to prevent the generation of high level spurious harmonics.

Figures 9 illustrates in more detailed the circuitry for another embodiment of a transceiver according to the invention. In this embodiment the transponder circuitry is connected across the capacitor to minimise the spurious harmonic levels. A comparator is connected across a sense resistor to sense the zero crossing of I_{ac}. The phase of the carrier is reversed on the zero crossings by XOR1. The carrier is generated in the carrier generator. If a high frequency carrier is required then a PLL multiplier is used to multiply up the resonant frequency. Alternatively, if a lower frequency carrier is required then a divider circuit can be used to divide down the resonant frequency. Processor circuitry generates the transponder data message which is used to PRK modulate the carrier frequency in XOR2. If required, waveshaping of the transmitted current is done by a multi-level modulator as shown in Figure 7(d).

Figures 10 to 13 illustrate an embodiment of the invention applied to a baggage

handling system. The transponder is encased with a two part foldable label which is mounted to a piece of baggage. As shown, a convenient mounting point for the label is the carry handle of the baggage.

One piece of the label includes the transponder which is in the form of a board mounted circuit. That is, the required components are mounted to a circuit board and interconnected to allow operation.

Accordingly, the transponder is easily retained on the baggage, and also easily removed, as required. When a piece of baggage passes a check point it is also passed through an interrogating signal which, in turn, causes the generation by the transponder of a response signal. This signal is received by the checking station and allows subsequent automatic redirection of the baggage to one of a plurality of predetermined holding areas.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that it may be embodied in many other forms.

DATED this 29th Day of January, 1998
PARAKAN PTY LTD

Attorney: JOHN B. REDFERN
Fellow Institute of Patent Attorneys of Australia
of SHELSTON WATERS

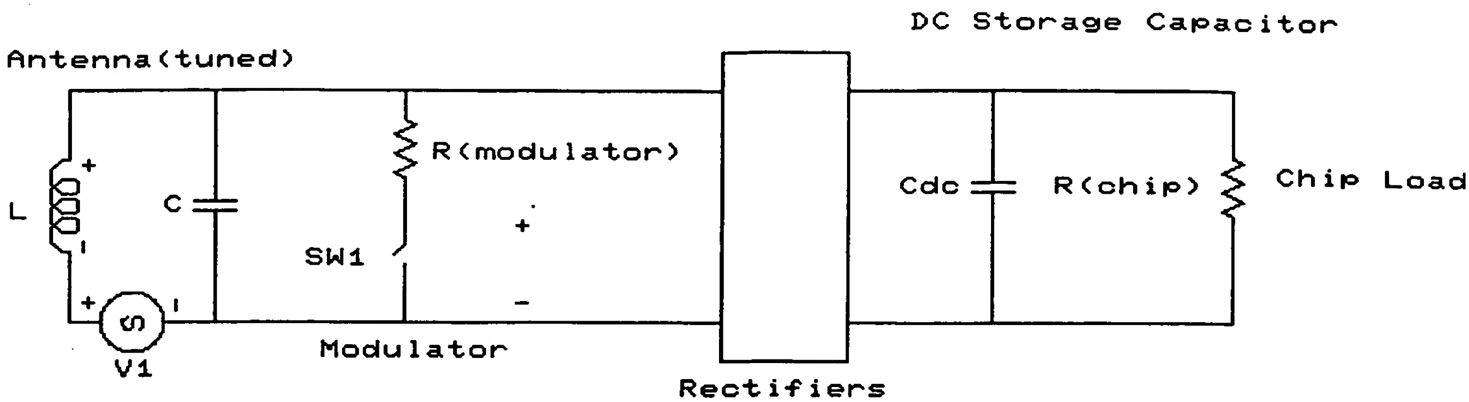
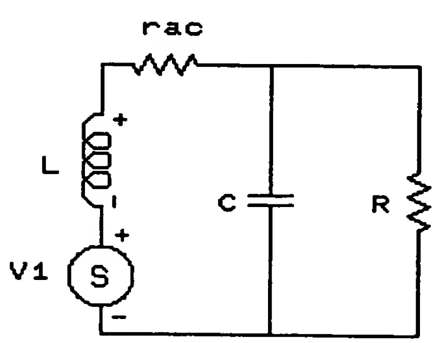


Figure 1 : Prior Art Transponder



$1/Qt=1/Qc+1/Qi$

$Qc=\omega RC \quad Qi=\omega L/rac$

$1/R=1/R(modulator)+1/R(chip)/2$

Figure 2 : Tuned Circuit Model for Prior Art

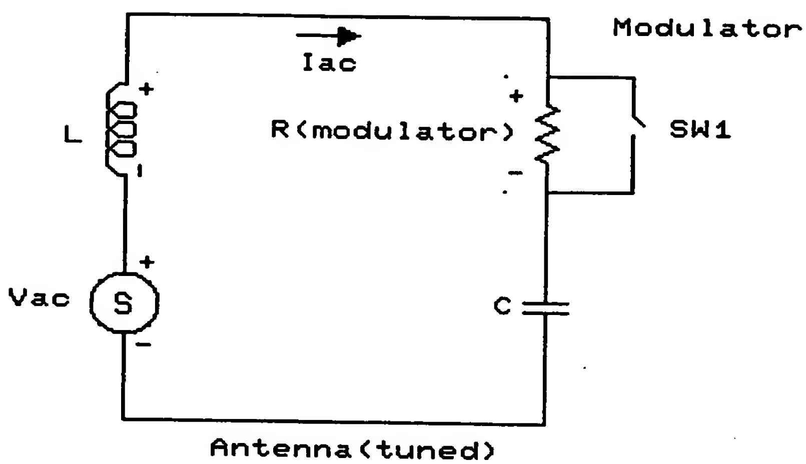


Figure 3 : Embodiment of Invention

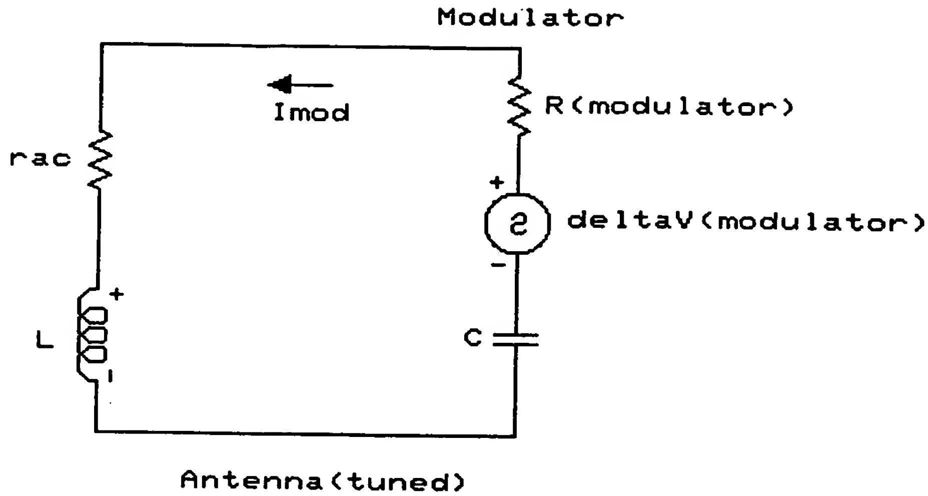


Figure 4(a) : Electrical Model of the Invention at Tuned Frequency

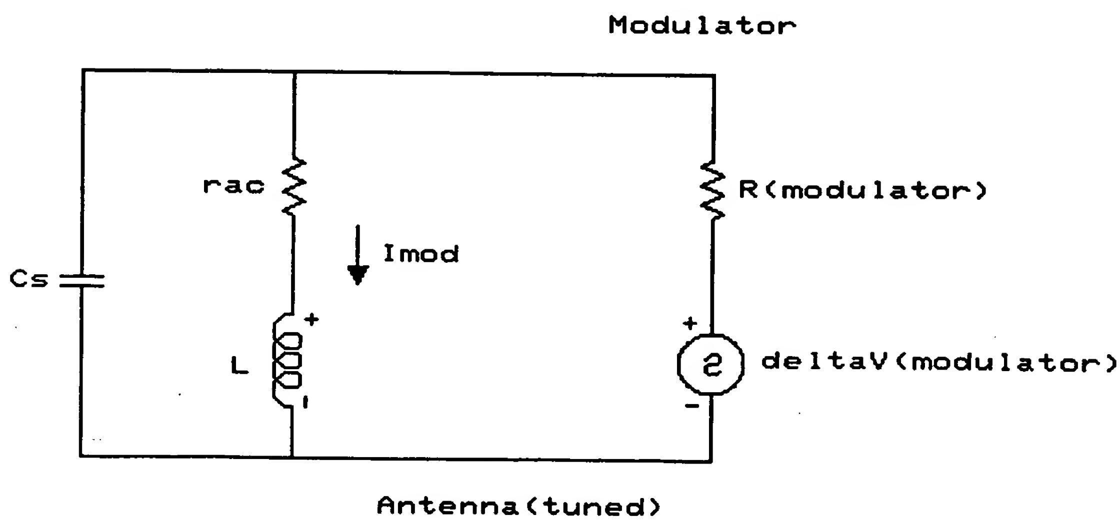


Figure 4(b) : Electrical Model of the Invention at Radio Frequency

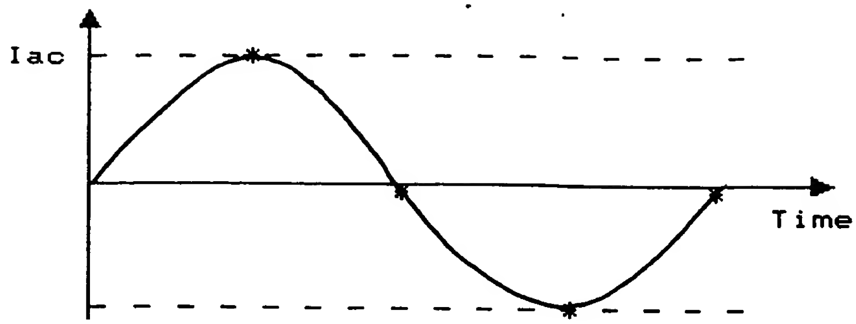


Figure 5(a) : Coil Resonant Current Iac

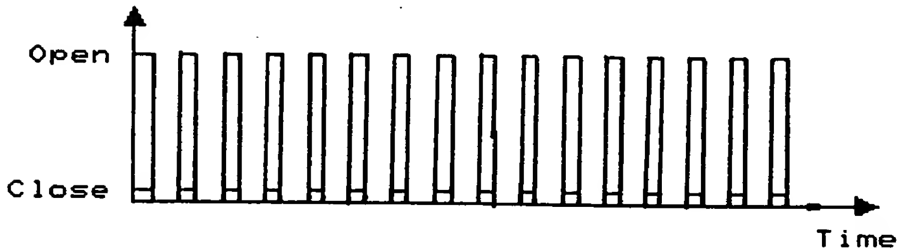


Figure 5(b) : Switch Function

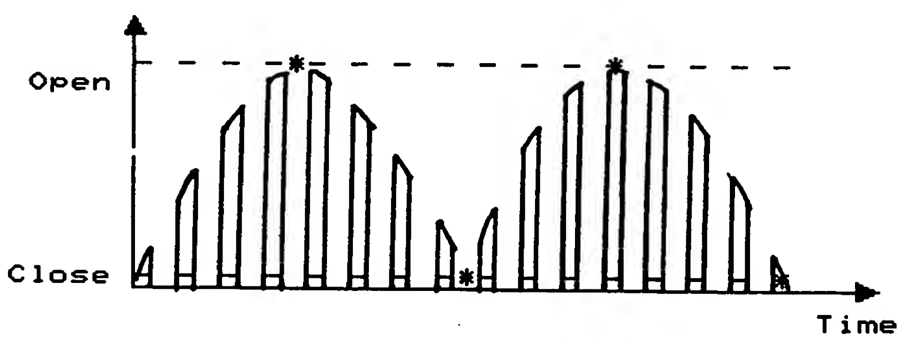


Figure 5(c) : Magnitude of V(modulator)

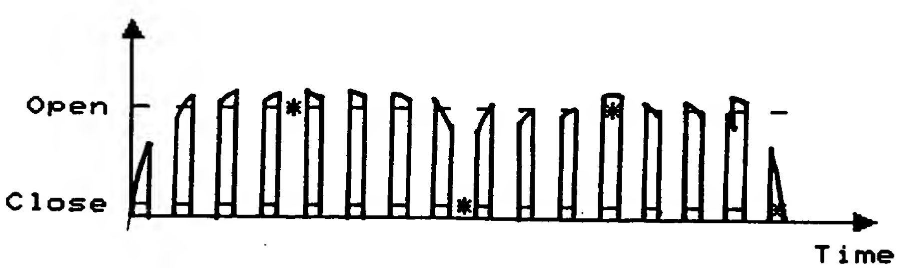


Figure 5(d) :Magnitude of V(modulator) with Waveshaping

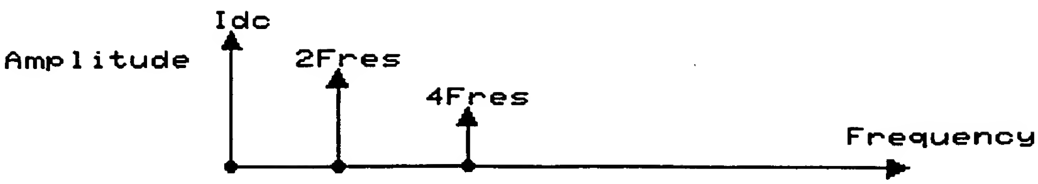


Figure 6(a) : Spectrum of Iac Fullwave Rectified

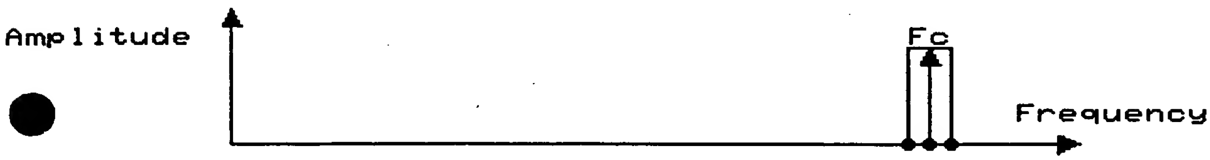


Figure 6(b) : Carrier Modulated with Data

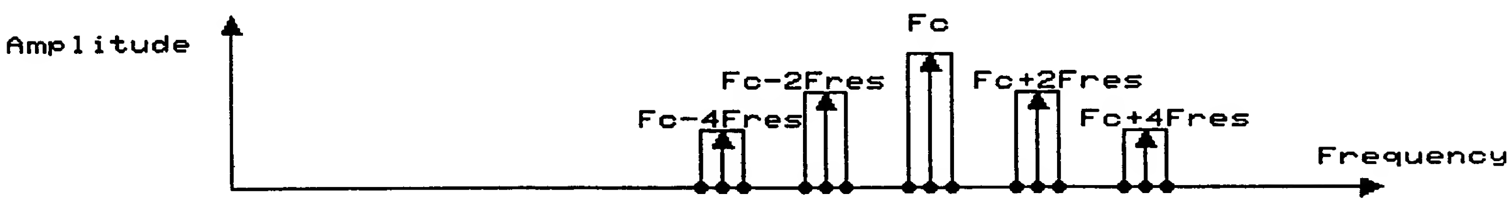


Figure 6(c) : Spectrum of V(modulator)

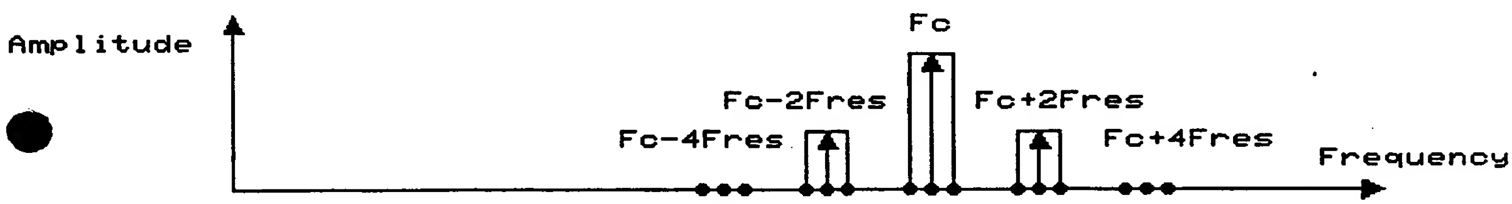


Figure 6(d) : Spectrum of V(modulator) with Waveshaping

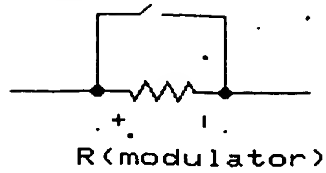


Figure 7(a) : Simple Switch Modulator

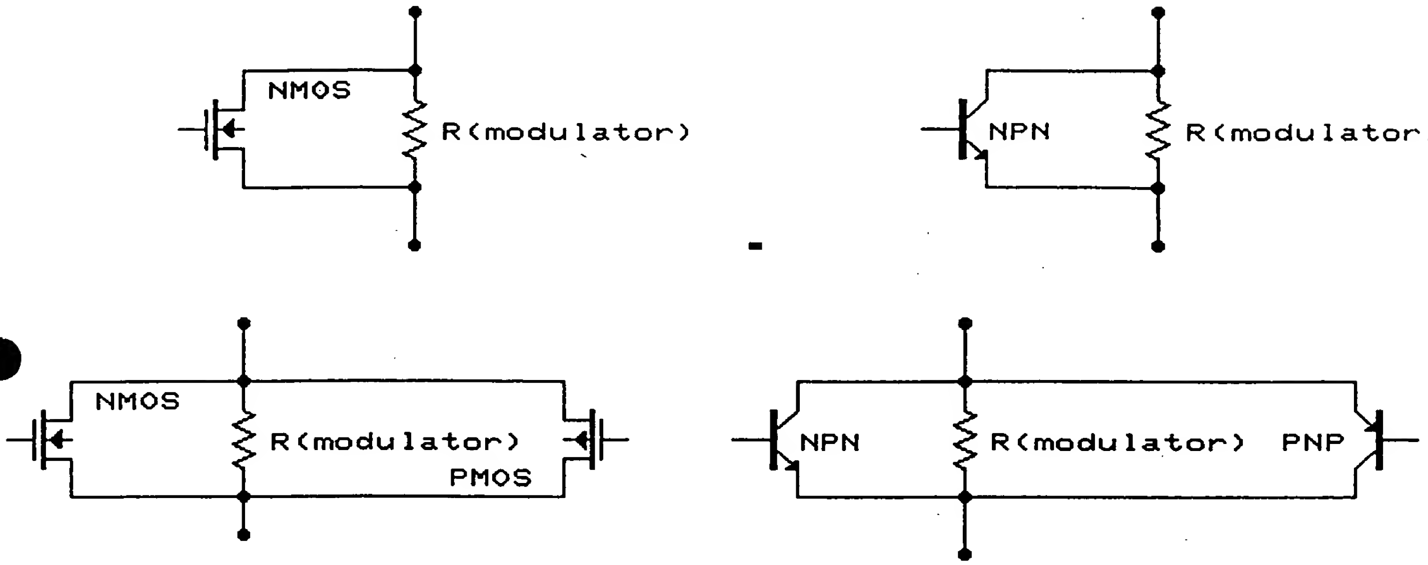


Figure 7(b) : Examples of Modulation Switches

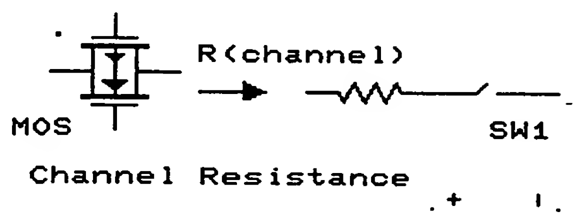


Figure 7(c) : Use of Channel Resistance to make Switchable Resistances

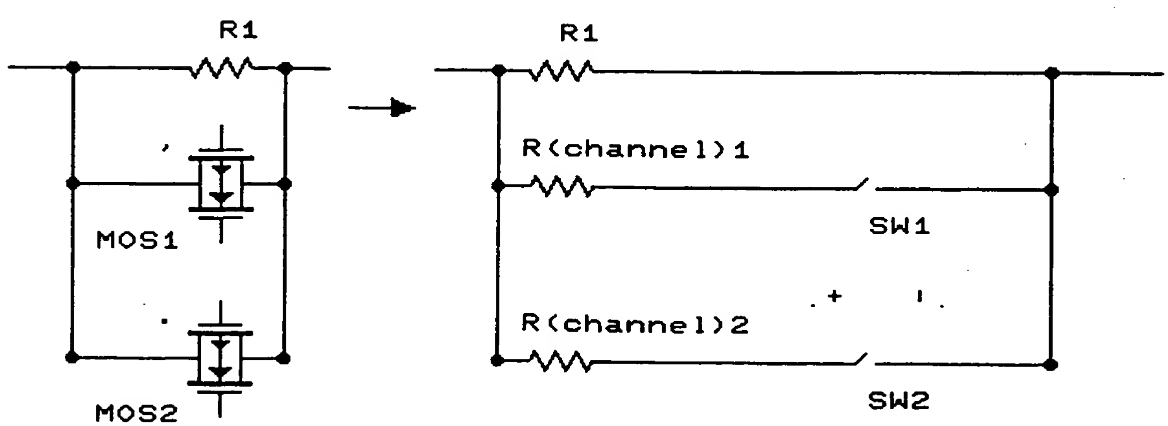


Figure 7(d) : Resistance varied between several values

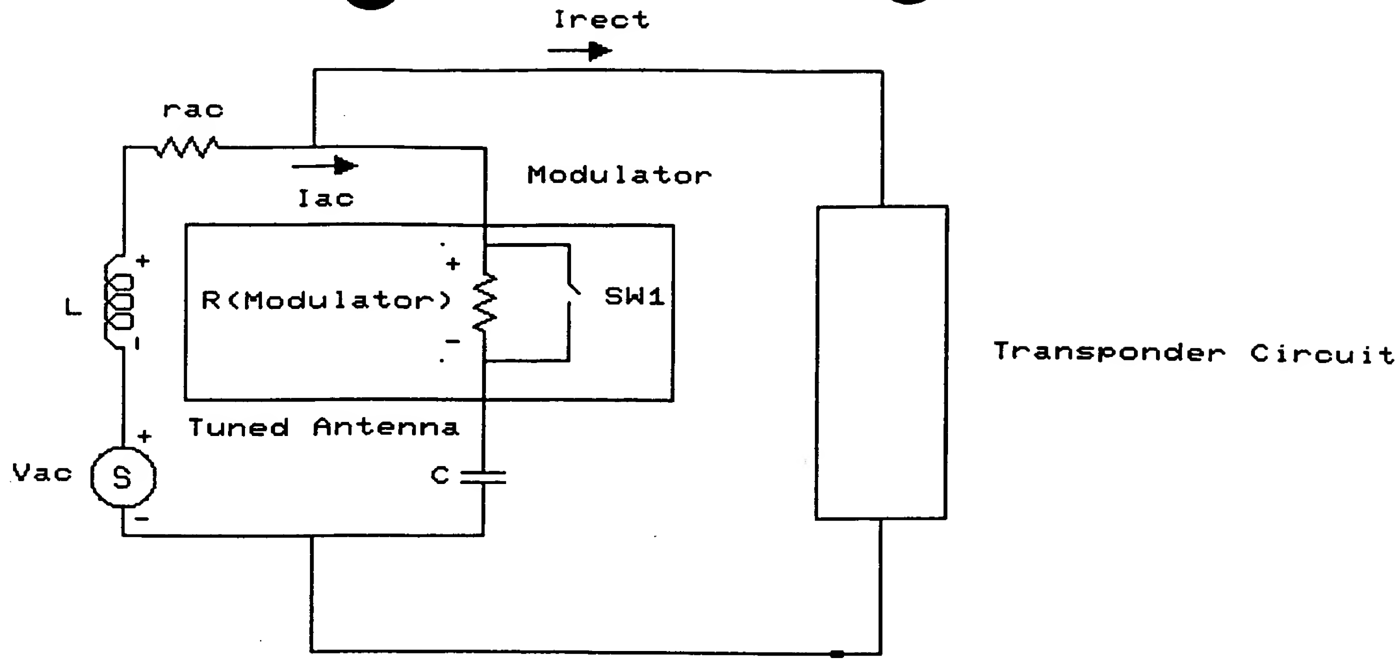


Figure 8(a) : Invention with Transponder connected across Coil

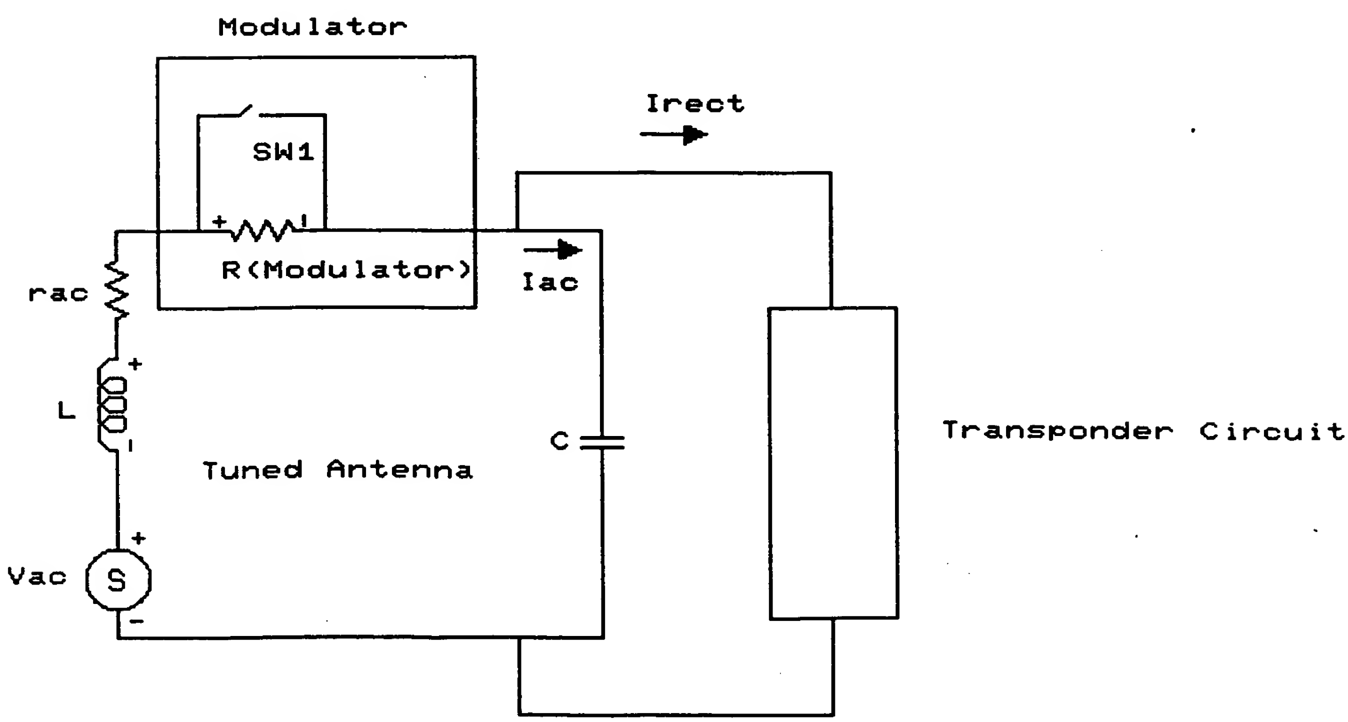


Figure 8(b) : Invention with Transponder connected across Tuning Capacitor

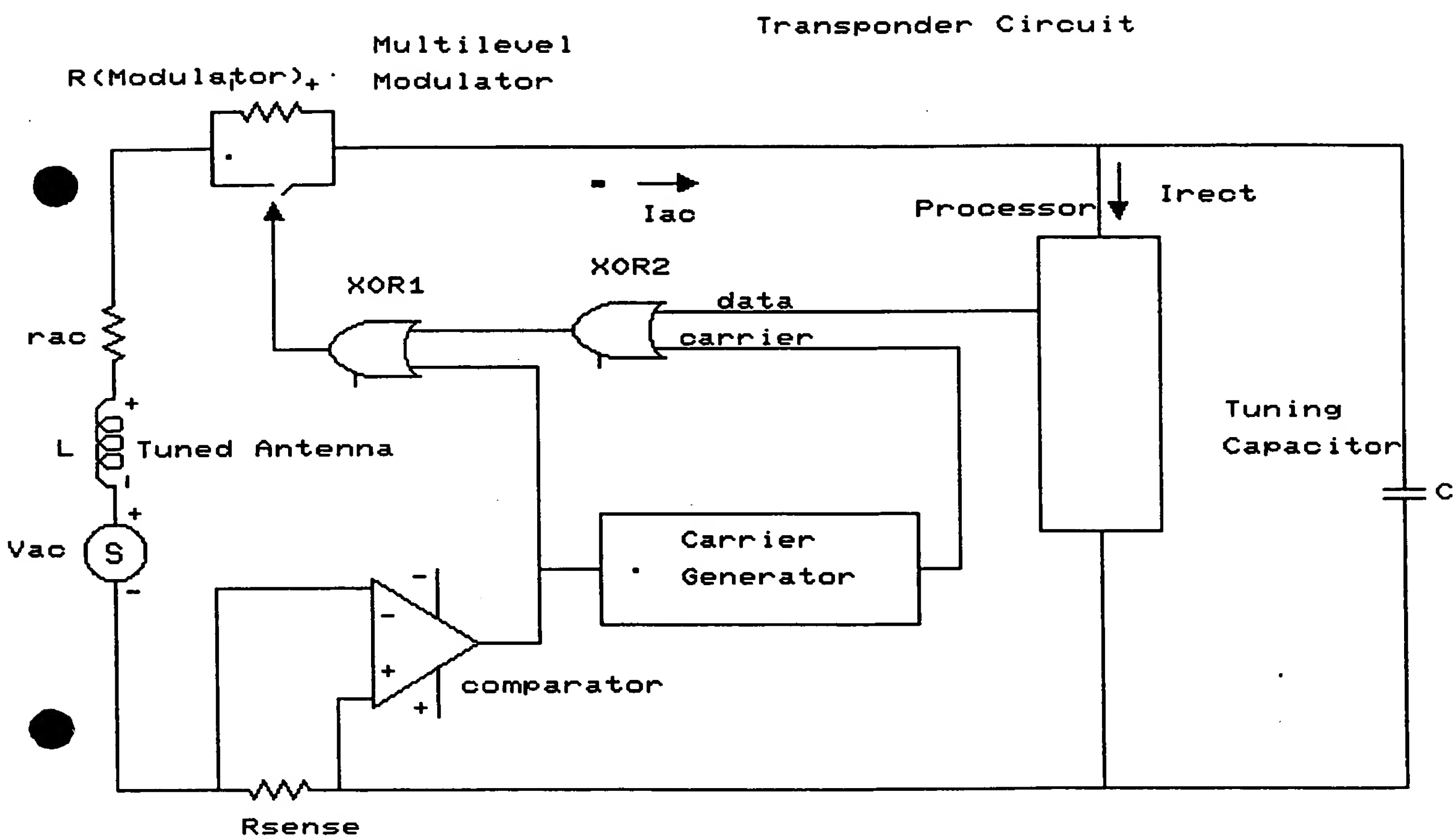


Figure 9 : Circuit embodiment of Invention

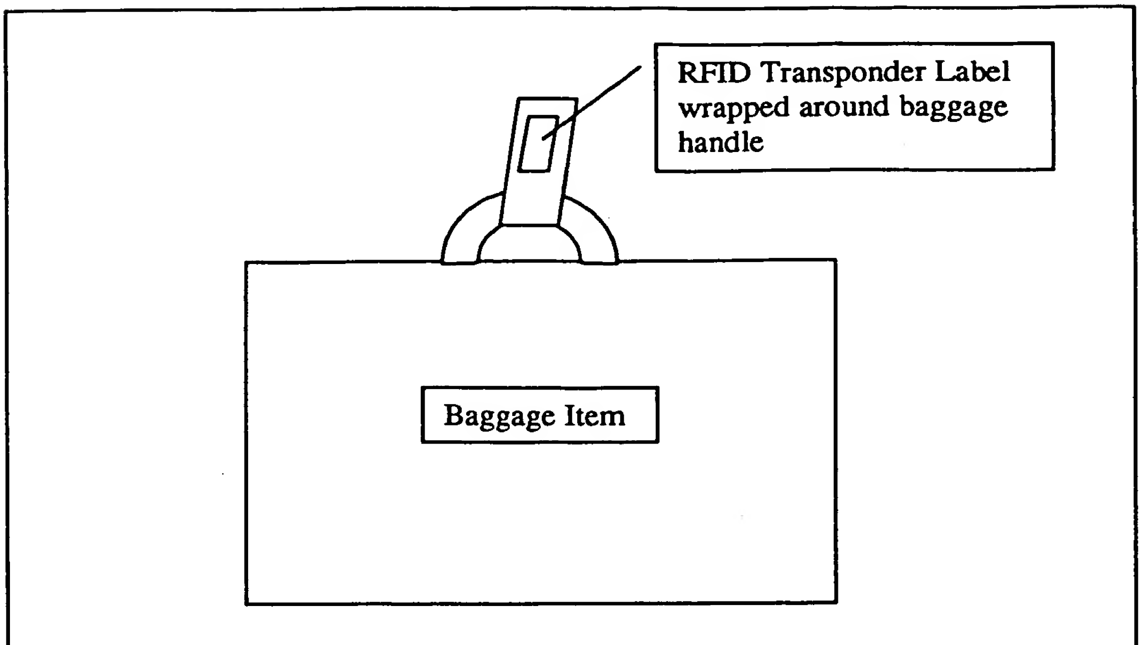


Figure 10 : Baggage item with RFID transponder label

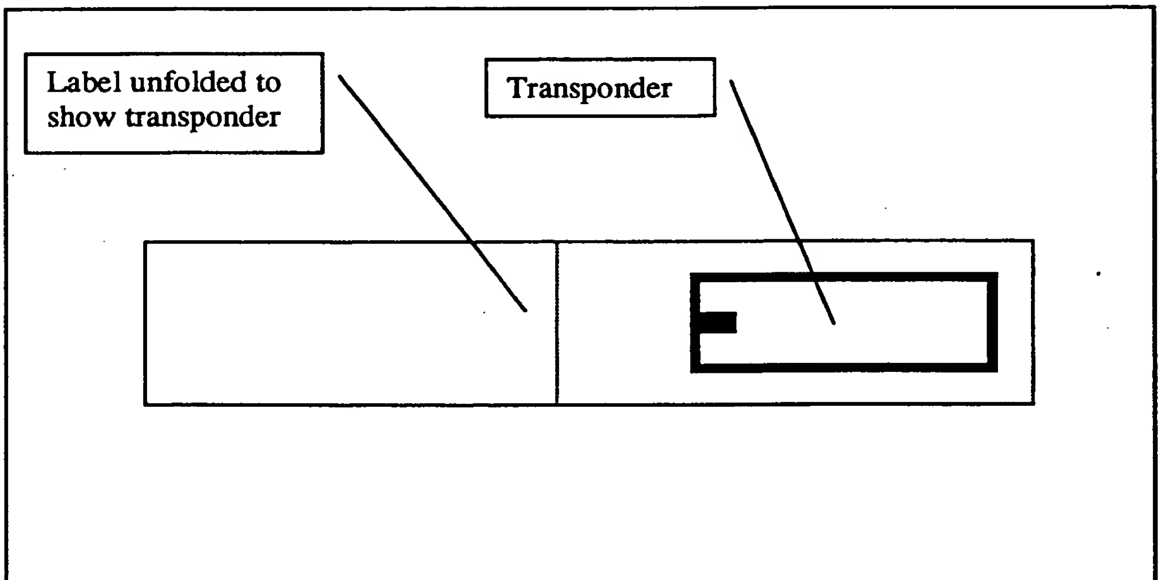


Figure 11 : RFID transponder on baggage label

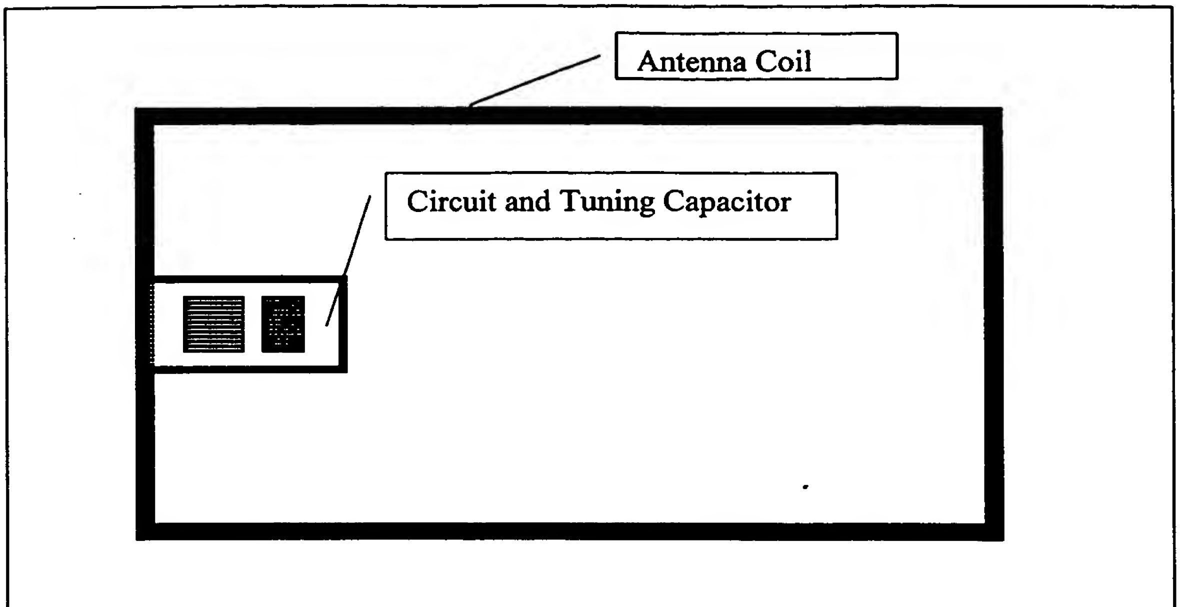


Figure 12 : Transponder Antenna Coil, Tuning Capacitor and Circuit

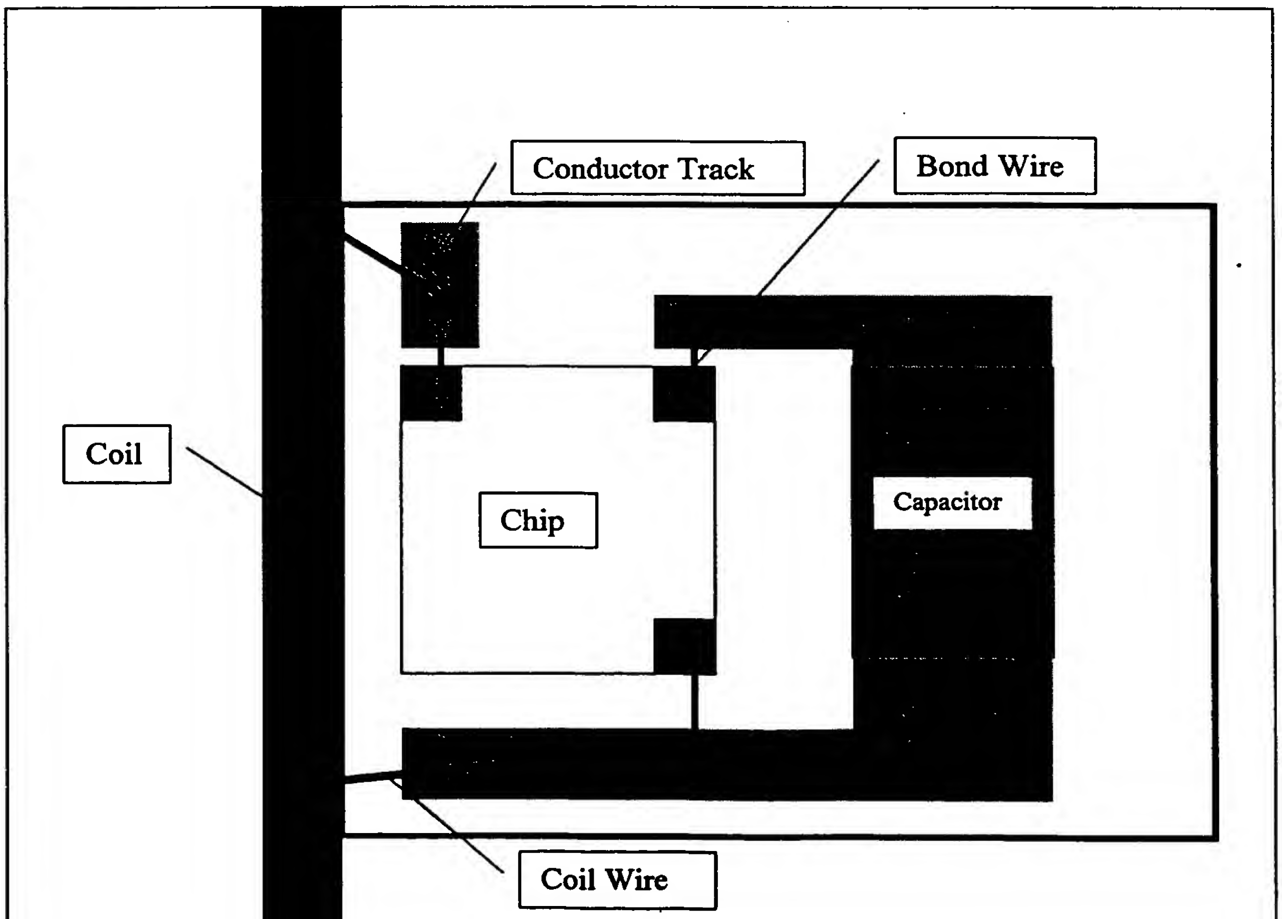


Figure 13 : Close-up of Circuit and Capacitor